A PRACTICAL MANUAL

AEN-221

RENEWABLE ENERGY AND GREEN TECHNOLOGY

FOR B.Sc. (AG) STUDENTS

(BIHAR AGRICULTURAL COLLEGE, SABOUR, BHAGALPUR)

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Experiment No: 1
AIM: Familiarization with renewable energy gadgets.

Renewable energy is defined as ‘a redestination that must rely on naturally existing energy' such as sunshine, wind and flowing water and wave power. Other than these natural resources, solar, biomass, geothermal and low impact hydro are eligible green power redestination options in voluntary 'green power' markets.

Why renewable energy gadgets?
The idea is to replace dependence on oil and carbon as sources of energy. Renewable energy gadgets popularly called 'green gadgets' are eco-smart as they use renewable energy. Energy Efficiency and clean sustainable energy will result in not only a cleaner environment but also greater energy independence for your country. Any investment in sustainable energy and technological innovation will go towards securing a resilient and secure future cushioned from the vagaries of oil exporting nations. In the micro level energy saving gadgets are economical and save money in the long run. Renewable energy sources are non-polluting and they help the environment by using clean energy resources. Cooking, lighting or cooling should become much simpler with at these inspiring gadgets. The world is slowly advancing toward an energy crisis of sorts. Dependency on non-renewable energy sources that can get depleted should be minimal. Renewable energy solutions can aid this emerging situation without exhausting the potential resources. There is a growing number of ways in which renewable energy gadgets are successfully used.

Solar: These devices use the radiant light and heat from the Sun. Solar technologies can be classified as - passive solar and active solar depending upon the way the energy is captured, converted and distributed. It was in the US in 1980 when space satellites, solar powered emerged on a large scale. The US researchers soon came out with solar cells that had 20% efficiency and by the year 2000 the efficiency of these panels has gone up to 24%. Advances in the field of **Photo voltaic systems** bring down the cost regularly. About a few years ago the cost of an installation of a complete Photovoltaic module system per watt was about 10 dollars including the cost of Solar panels, inverters and related electrical gears. Cost for the solar panels will go down once mass production begins. Solar panels are integrated into forms of roofing and shingles making them cost effective in the long run. Improvement in the manufacturing process of polycrystalline / monocrystalline cells and amorphous Silicon solar cells will eventually drive the per watt cost down. For the discerning consumers, solar chargers are available both on expensive and economical ends. From smaller gadgets to power laptops, from backpacks to fold-up chargers, there are great many things that can be charged this way. Solar power is probably the most widely available option for charging up off-grid. While purchasing a solar charger, be sure to see that it generate enough watts to feed the gadget. Also look at how long it takes to charge up. This is similar to someone sunbathing in an area that is hardly sunny enough. It might take days of sunbathing before there is enough juice to charge the gadget.

Wind: Wind is a renewable energy source predominantly used to generate electricity. Today's devices capturing wind's kinetic energy are somewhat akin to the old fashioned windmills. The wind available in nature gets transformed into useful electrical energy through the wind turbines

which perform the conversion. Wind power meets about 1% of the world wide electrical energy consumption. Charging gadgets through natural resources is becoming much more practical than probably putting a turbine on the roof. For instance wind chargers are small and light and can be hooked to a bike to gather wind power while one rides. It can also be hung out on the window to catch a strong breeze. There is yet another device that can capture wind power through a simple suction cup.

Kinetic: Whereas turbines transform the kinetic energy of the river into mechanical energy; Electricity is produced by joint efforts of turbines and generators. Moving water or hydro power and energy is captured from here and used for different purposes. Although the generation and use of energy through kinetic resources is still in a developing stage yet the iYo-Yo can charge iPhone and one can charge the battery power of a mobile phone with a strap-on charger. These have lower rate of efficiency when it comes to how much energy it can harvest with movement.

Rainwater: Rainwater may be converted into renewable energy and it contributes to approximately 18% of the total energy consumption in the world.

Geothermal: Geothermal energy is essentially the heat that comes from within the earth. The term 'geothermal' is derived from Greek origin, with 'Geo' implies earth and 'Therme' implies heat. The geothermal energy generated by the Earth's interior is renewable energy. California generates the highest amount of electricity from the usage of geothermal energy.

Biomass: This is another renewable energy source which includes animal and plant matter and biodegradable wastes. Human excreta, manure, waste from slaughterhouse and sewer form biomass content. Renewable energy products like biodiesel and ethanol are used as energy source in boilers and internal combustion engines.

Renewable energy gadgets: Eco friendly gadgets are the order of the day as people are becoming more and more environment conscious and beginning to see huge advantages of green technology. Renewable energy gadgets as such do not cause any harm but they serve the purpose best.

LED Lights:
Light Emitting Diodes (LED) have slowly started replacing incandescent bulbs and fluorescent bulbs despite their high initial costs. The tell-tale indicator LED has slowly metamorphed into high intensity light source. LED lights consume at least 50 % less power, have a long life - at least in excess of 50,000 hours, require no wounded ballast, contain no mercury and have a wider range of working temperature, from -40 to 45 degree C. Compare this with the standard filament incandescent bulb which has a life of about 1000 hours, has about 3 % efficiency and will not tolerate vibration beyond a point.
Though Compact Fluorescent lamps (CFL) offer higher efficiencies compared with incandescent bulbs, they contain hazardous mercury and offer poor *Color Rendering Index (CRI)*. In other words, their color temperature is colder and not warm like an incandescent bulb. LED lamps excel in efficiency and environmental friendliness.
LED lamp circuits are simple constant current supplies which do not require high voltage wound components. Semiconductor LEDs offer another benefit - the light output can be controlled in

terms of color and spatial distribution by electronics to create smart lights which adjust to the environment or mood.

Solar energy gadgets

Solar devices for renewable energy generation are available aplenty. But most of these are either chargers for mobiles and electronic devices or can be used when the battery is depleted.
Small solar energy chargers can be connected to different devices and also have built in battery for excess power storage. The ability to plug in directly into the main electricity makes the solar charger a favorable product. These devices charge at a much faster rate but most of the time their usefulness is limited to daytime hours. Solar energy battery packs focus on storing energy than charging the connected device directly.
For bigger devices that consume extra power like laptop computers, solar generators are needed. They come in a range of shapes, sizes and prices. The solar charger energized in direct sunshine is an excellent solution for an array of other devices as well that consume more power.
There are stand alone solar powered generators that can match the performance of even petrol driven competitors. However, they are costly and bulky and therefore not an easy buy. There are lightweight and far more practical solar generators that are ideal portable energy solutions.
There are gadgets that have built-in solar panels. The solar phone is one such instance. Solar energy panels can be construed as a hybrid battery/charger for mobile devices including most mobile phones, iPods, PDAs and other portables. The power can bask in the sunshine and glow warm and it can also be plugged into the wall for some extra juice ready when there is an emergency.

- A new solar wetsuit also harnesses sun's energy and it gives the wearer 30% more heat especially when surfing in cold conditions.
- There is a green geek wear which comes in black and is ergonomically designed with storage compartments/pockets that are strategically located. The battery charged pack gets its juice from the solar panels that can be slipped into the back of the jacket.
- An extensive range of solar powered toys and gifts are available for parents who would want to present their children with a green message. These toys could be educational and consume renewable energy - quite suitable for school children who are inquisitive.
- Corporate gifts to reinforce environmental credentials like rechargeable solar radios, lanterns and torches or phones, cameras and iPods are ideal during camping, caravanning, boating, trekking and skiing ... or high quality solar garden lights with water features, the possibilities are endless.
- Solar powered cooking with solar cookers is a viable alternative to gas and electricity. Some of the designs are lightweight with easy to get materials. They can get hot enough even to cook meat.
- Solar powered air conditioners should cool one's home inside while the sun is scorching outside.
- A portable solar water heater is designed to make available cheap and easy hot water. There is no need for any indoor plumbing or electricity here.
- **Wind turbines**: Molded, efficient and lightweight these compact wind turbines start spinning at just 2.5 m /s wind speed producing power at 12 m/s. A personal wind

turbine is much smaller than a huge wind farm fodder and is designed for charging batteries.

- There is yet another spin dryer that uses centrifugal force to dry clothes quickly and efficiently. The dryer uses the same amount of energy that a regular cloth dryer uses in the first fifteen seconds of the operation.
- Eco gadgets are innovative green gadgets that use renewable energy. LED torches, solar chargers and next generation lighting consume little power and are energy efficient. Dynamos using new technology can provide wind up charging systems for many portable torches, radios and MP3 players.
- A portable cell phone charger does not contain a battery but generates power by turning the small handle on the side. Two minutes of turning can give approximately six minutes of cell phone time.

The green geek gadgetry which has eco friendly application is aplenty. There is a nature indoor composter that allows recycling the waste food easily and quickly without a garden and without specialized food waste collection service. This composter is capable of breaking down around 120 lbs of food waste every month. Once the food is broken down, the compost can be relieved from the bottom container of the composter. The heat kills the bacteria and destroys majority of smells. The carbon filter inside the composter that regulates the odor needs replacement every five years.

Renewable energy gadgets use novel energy technologies which can help avert global warming caused by the astounding build up of gases and fumes. The most widely used alternative renewable technology source is solar power in the form of solar panels and photovoltaic cells. Another widely used clean energy is wind power from wind turbines. The use of renewable gadgets will save the environment from the batteries that emit nasty chemicals and heavy metals polluting and poisoning the natural eco systems and keep the planet safe.

Experiment No: 2
AIM: To study biogas plants

Floating Gasholder Biogas Plant: (KVIC Model)
The design consists of deep well-shaped underground digester connected with inlet and outlet pipes at its bottom. The inlet and outlet pipes are separated by a partition wall dividing the 3/4s of the total height into two parts. A mild steel gas storage drum that is inverted over the slurry and goes up and down around a guide pipe with the accumulation and withdrawal of gas. Now FRP (fibre-reinforced plastic) and ferrocement gas holders are also being used in this type of plant. The gas holder is separated from the digester. A partition is provided in the digester to encourage circulation. The floating gas holder provided at the top of the digester helps to keep the pressure constant. The floating gas holder rises when the pressure is increased due to production of gas and allows the generated gas to be let out through the gas supply pipe. It lowers when the pressure is decreased to stop the supply of the biogas (Fig. 2.1).

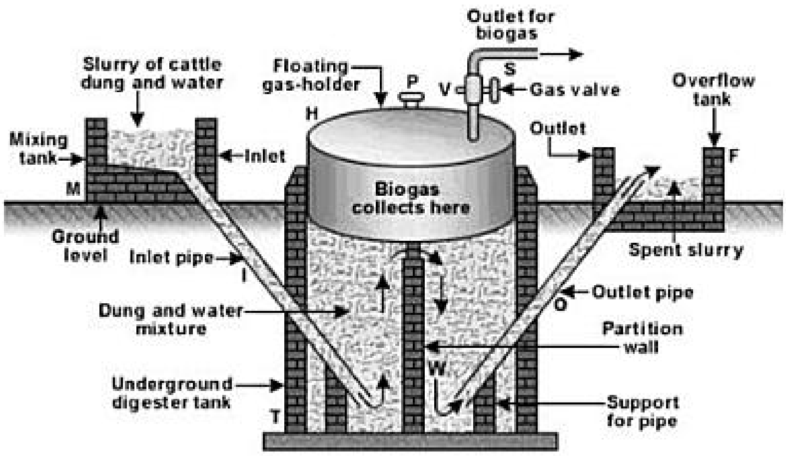

Fig.2.1 Floating gas holder biogas plant: (KVIC model)

Digester is 3.5-6.5 m in depth and 1.2 to 1.6 m in diameter. The size of the gas holder depends on requirement of gas per day e.g. for cooking the food of one person gas required is 0.24 m^3 therefore for the family of six members total gas required per day is 1.44m^3 and thus the size of gasholder must be more than this. It should be approximately 2m^3. From experimental observations it has been observed that 1 kg of cow dung gives 0.036 m3 of gas 1 cow or cattle gives 10 kg dung every day. i.e. 0.36 m^3 gas that is produced by the dung of one cattle. Thus to get sufficient biogas we need the dung of 5 cattle.

The size of the digester depends on the retention time and for cow dung it varies from 20-55 days, depending on temperature of location. Thus the size of digester varies from place to place to get same amount of gas. For example, the size of digester of biogas plant having capacity 2m^3 will be smaller in Maharashtra than in Himachal Pradesh.

Janatha Model

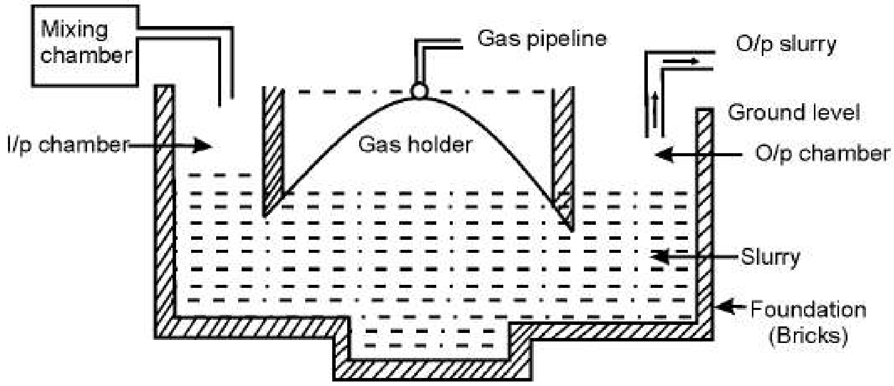

Fig.2.2 Fixed domed biogas plant (Jantha design)

In this biogas plant the gasholder is dome type and fixed one. Digester is cylindrical with flat base cemented at bottom. Inlet and outlet chambers are constructed for putting fresh slurry in and to take digested slurry out. The input and output slurry chambers are relatively bigger than KVIC plant. The gas is collected in between the dome and digester. When gas is generated, it develops the pressure within a dome and it suppresses the slurry down. This results in rise in the level of the input (i/p) and output (o/p) slurry chambers. On opening the pipe gas is released due to pressure of the slurry in i/p and o/p chambers. The gas releases till the levels in i/p and o/p chambers and digester become equal. As a result the rate of gas released in this model is not constant and decreases with time. The size of the biogas plant is decided by the gas generated or required every day i.e. 2, 4, 6, 8, 10 m^3, accordingly the volume of gas collecting dome is decided. The size of the digester depends on retention time similar to KVIC Model. As retention time increases the volume of digester increases though volume of gasholder remains constant. The construction cost of the Janatha model is relatively less than KVIC model. The main feature of this model is that the digester and the gas holder are integrated parts of the brick masonry structure. The digester is made of a shallow well having a dome shaped roof on it. The inlet and outlet chambers are connected with the digester through large chutes. These chambers are above the level of the junction of the dome and the cylindrical well. The gas pipe is fitted on the crown of the masonry dome (Fig. 2.2).

Deenbandhu model

This model is designed on the basis of the principal of minimization of the surface area of a biogas plant to reduce its installation cost without sacrificing the functional efficiency. The design consists of two spheres of different diameters, joined at their bases. The structure thus formed acts as the digester or fermentation chamber, as well as the gas storage chamber. The digester is connected with the inlet pipe and outlet tank. The upper part above the normal slurry level of the outlet tank is designed to accommodate the slurry to be displaced from the digester with the generation and accumulation of biogas (Fig. 2.3). Schematic diagram of Deenbandhu model is as shown in figure below.

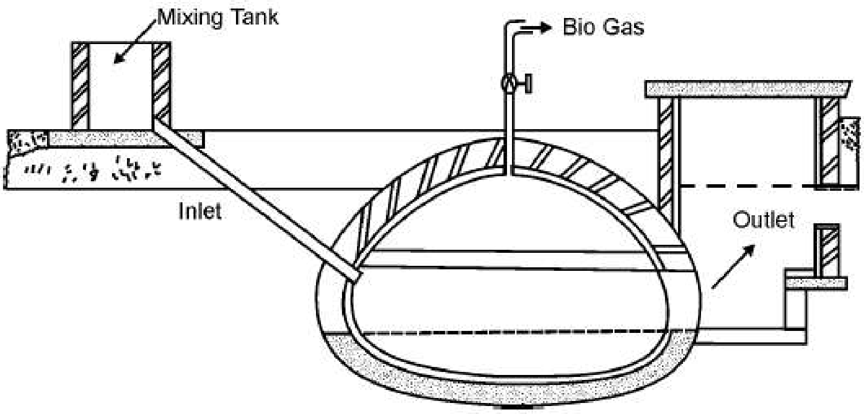

Fig. 2.3 Fixed domed plant (Deenbandhu design)

The asbestos cement pipe is used for inlet and is embedded in digester wall at fixed position however the structure and nature of dome is same as that of Jantha model. The principle and working of Deenbandhu model is similar to that of Jantha model. Initially a level of slurry in digester and output slurry chamber is equal. As gas is produced there develops the pressure in the dome and it suppresses the slurry level in the digester with the increase in the level of the o/p chamber. When one opens the gas pipe, due to level difference between digester and o/p chamber, the gas comes out till the levels in both chamber and digester become equal.

Experiment No: 3
AIM: To study the production process of biodiesel

Biodiesel Production Process: Biodiesel is produced from vegetable oils or animal fats and an alcohol, through a transesterification reaction. This chemical reaction converts an ester (vegetable oil or animal fat) into a mixture of esters of the fatty acids that makes up the oil (or fat). Biodiesel is obtained from the purification of the mixture of fatty acid methyl esters (FAME). A catalyst is used to accelerate the reaction (Fig. 3.1). According to the catalyst used, transesterification can be basic, acidic or enzymatic, the former being the most frequently used, as indicated in Box 3.1.

Box 3.1 Transesterification Reactions for Biodiesel Production Basic. Most frequently used at all production scales. Acid. Less frequent in industrial production, sometimes used a first stage with highly acidic raw materials. Enzymatic. Less used; the enzymes are usually lipases.

A generic transesterification reaction is presented in Eq. (3.1); RCOOR' indicates an ester, R"OH an alcohol, R'OH another alcohol (glycerol), RCOOR" an ester mixture and cat a catalyst:

$$\mathbf{RCOOR' + R''OH \overset{cat}{\Leftrightarrow} R'OH + RCOOR''} \qquad (3.1)$$

When methanol is the alcohol used in the transesterification process, the product of the reaction is a mixture of methyl esters; similarly, if ethanol were used, the reaction product would be a mixture of ethyl esters. In both cases, glycerin will be the co-product of the reaction. This is shown schematically in Figs. 3.1 and 3.2.

$$\begin{array}{lcccc} H_2C-OCOR_1 & & H_2C-OH & & CH_3-OCOR_1 \\ \vert & & \vert & & \\ HC-OCOR_2 & +3\,CH_3OH \overset{NaOH}{} & HC-OH & + & CH_3-OCOR_2 \\ \vert & & \vert & & \\ H_2C-OCOR_3 & & H_2C-OH & & CH_3-OCOR_3 \end{array}$$

Fig. 3.1 Basic transesterification reaction with methanol

$$\begin{array}{lcccc} H_2C-OCOR_1 & & H_2C-OH & & CH_3CH_2-OCOR_1 \\ \vert & & \vert & & \\ HC-OCOR_2 & +3\,CH_3CH_2OH \overset{NaOH}{} & HC-OH & + & CH_3CH_2-OCOR_2 \\ \vert & & \vert & & \\ H_2C-OCOR_3 & & H_2C-OH & & CH_3CH_2-OCOR_3 \end{array}$$

Fig. 3.2 Basic transesterification reaction with ethanol

Although transesterification is the most important step in biodiesel production (since it originates the mixture of esters), additional steps are necessary to obtain a product that complies with international standards, as shown in Box 3.2. In consequence, once the chemical reaction is completed and the two phases (mix of esters and glycerin) are separated, the mix of methyl esters must be purified to reduce the concentration of contaminants to acceptable levels. These include remnants of catalyst, water and methanol; the latter is usually mixed in excess proportion with the raw materials in order to achieve higher conversion efficiency in the transesterification reaction. In the following sections the steps of the purification process will be described in detail.

Box 3.2 Stages of Biodiesel Production Process
Treatment of raw materials
Alcohol-catalyst mixing
Chemical reaction
Separation of the reaction products
Purification of the reaction products

Experiment No: 4
AIM: Construction details of different types of gasifiers, testing of gasifiers

Four different types of gasifiers are:

1. Updraft
2. Downdraft
3. Fluidized
4. Entrained bed

The schematic diagram of these gasifiers are shown in Fig. 4.1.

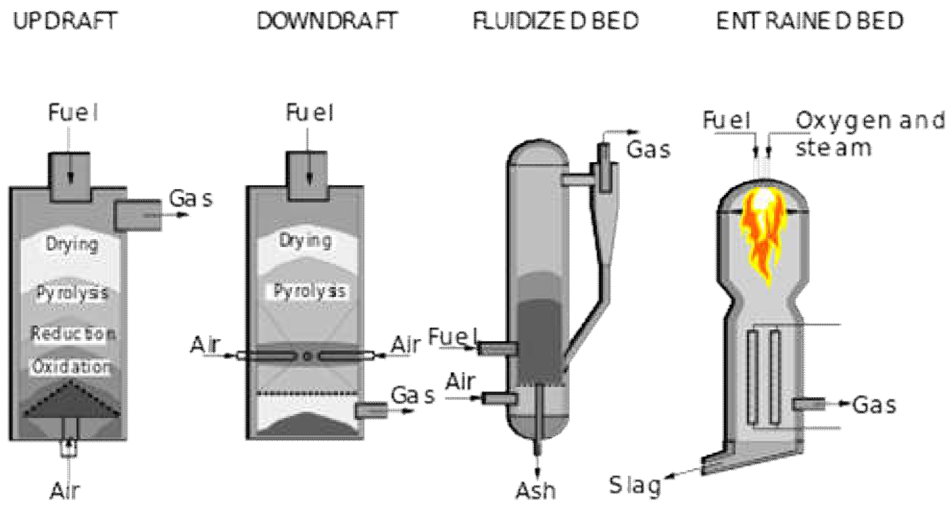

Fig. 4.1 Different types of gasifiers

The working details of these gasifiers are as below:

1. Updraft fixed bed The biomass is fed in at the top of the gasifier, and the air, oxygen or steam intake is at the bottom, hence the biomass and gases move in opposite directions. Some of the resulting char falls and burns to provide heat. The methane and tar-rich gas leaves at the top of the gasifier, and the ash falls from the grate for collection at the bottom of the gasifier.

2. Downdraft fixed bed The biomass is fed in at the top of the gasifier and the air,and oxygen or steam intake is also at the top or from the sides, hence the biomass and gases move in the same direction. Some of the biomass is burnt, falling through the gasifier throat to form a bed of hot charcoal which the gases have to pass through (a reaction zone). This ensures a fairly high quality syngas, which leaves at the base of the gasifier, with ash collected under the grate

3a. Circulating fluidised bed (CFB) A bed of fine inert material has air, oxygen or steam blown upwards through it fast enough (5-10m/s) to suspend material throughout the gasifier. Biomass is fed in from the side, is suspended, and combusts providing heat, or reacts to form syngas. The mixture of syngas and particles are separated using a cyclone, with material returned into the base of the gasifier. Operates at temperatures below 900°C to avoid ash melting and sticking. Can be pressurized

3b. Dual fluidised bed (Dual FB) This system has two chambers – a gasifier and a combustor. Biomass is fed into the CFB / BFB gasification chamber, and converted to nitrogen-free syngas and char using steam. The char is burnt in air in the CFB / BFB combustion chamber, heating the accompanying bed particles. This hot bed material is then fed back into the gasification chamber, providing the indirect reaction heat. Cyclones remove any CFB chamber syngas or flue gas. Operates at temperatures below 900°C to avoid ash melting and sticking. Could be pressurized.
4a. Entrained flow (EF) Powdered biomass is fed into a gasifier with pressurised oxygen and/or steam. A turbulent flame at the top of the gasifier burns some of the biomass, providing large amounts of heat, at high temperature (1200-1500°C), for fast conversion of biomass into very high quality syngas. The ash melts onto the gasifier walls, and is discharged as molten slag.
4b. Bubbling fluidised bed (BFB) A bed of fine inert material sits at the gasifier bottom, with air, oxygen or steam being blown upwards through the bed just fast enough (1-3m/s) to agitate the material. Biomass is fed in from the side, mixes, and combusts or forms syngas which leaves upwards. Operates at temperatures below 900°C to avoid ash melting and sticking. Can be pressurized.

Comparison of gasification technologies Gasifiers are compared in terms of:

- Feedstock requirements – which gasifier types are most suitable for which feedstocks? What feedstock preparation is needed for each type?
- Ability and potential to meet syngas quality requirements – what quality of syngas is produced? Does this make particular gasifier types more suitable for particular syngas conversion processes?
- Development status and operating experience – how advanced are the developers of each gasifier type? Have there been failed projects, and if so, why?
- Current and future scales – can the gasifier type meet the required scale now or in the future? Costs – what data are available on the costs of the gasifier types? What conclusions can be drawn from this?

Experiment No: 5
AIM: Briquette preparation from biomass

Briquetting is a technological method of compressing and densifying the bulky raw material, thereby reducing its volume-weight ratio and making it usable for various purposes. The vital requirement of briquette formation from woody biomass is the destruction of the elasticity of the wood, which could be done either by previous heat treatment or by a high pressure or by a combination of both. There are two processes of briquetting biomass, namely direct compaction and compaction after pyrolysis or carbonization as mentioned below (Fig. 5.1):

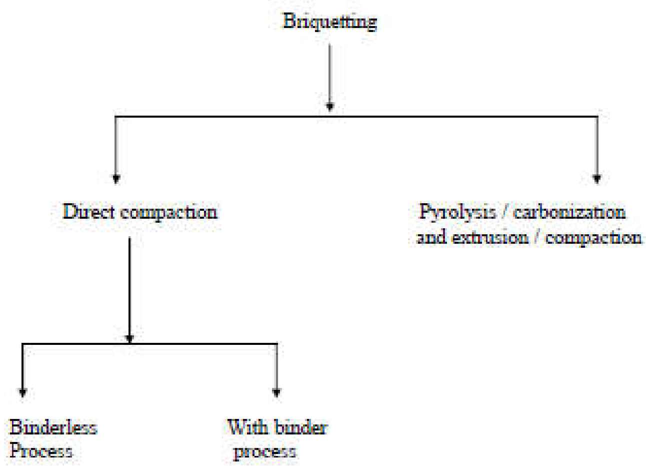

Fig. 5.1 Process of Briquetting biomass

Direct compaction There are two technologies for the manufacture of briquettes by directly compacting the biomass without previous heat treatment.
(i) Binderless process
The process involves two steps
(a) **Semi-fluidizing the biomass***:* Biomass is semi-fluidized through the application of high pressure in the range of 1200 – 2000 kg/cm^2, at which conditioned biomass gets heated to a temperature of about 182°C and the lignin present in biomass begins to flow and act as binder, provides mechanical support and repels water.
(b) **Extracting the densified material** The semi-fluidized biomass is densified through electrically operated briquetting machines available in the range of 100-300 kg/h, The cost of such briquetting units depend upon its capacity and is in between Rs. 3 lakh to 20 lakhs.
(ii) With binder process In this process, the biomass requires addition of some external binding materials like molasses, dung slurry, lignasulphonate, sodium silicate etc. The briquetting machines operate at lower pressure range of 500-1000 kg/cm2 and are powered by electricity. Such machines are available in the capacity range of 100 to 400 kg/h.

Pyrolysis / carbonization and extrusion
The elasticity of biomass could be destroyed by previous heat treatment of the biomass. Pyrolysis is the process of destructive distillation of organic materials heated at slow rate at about 270°C in the absence or minimum presence of oxygen. During process of pyrolysis, solid char, liquid tar and combustible gases besides organic liquids are produced. The nature and

quantum of these products depend on various factors such as composition of biomass, residence time in kiln and temperature. During the pyrolysis, the fibre content of biomass is broken, which later facilitates in briquetting of produced charcoal. The charcoal is briquetted through extrusion / compaction process.

Power Operated Briquetting Machines

The Indian Grassland and Fodder Research Institute (IGFRI), Jhansi has developed.

1. Reciprocating crank – piston drive press
2. Auger conveyor type press.

1. **Reciprocating Crank – Piston Drive Press.**

The press mainly consists of the frame, crank and piston mechanism, compression chamber, feeding hopper and V belt drive power transmission system. The machine is operated by a 10 KW electric motor. The piston reciprocates at a speed of 80 strokes/min with a stroke length of 18 cm. Chaffed grass/straw mixed with leguminous material in the ratio of 1:1 is fed into the compression chamber through the hopper and is pressed during the forward stroke of the piston. The application of pressure and the capacity of the machine depend on the diameter of the compression chamber.

2. **Auger Conveyor Type Press**

The machine consists of an auger, auger housing, multi hole pressure plate, feeding hopper and flat belt power transmission system. It is also operated by a 10 kw electric motor. The auger rotates at a speed of 200 rpm and the capacity of the machine varies from 40 to 60 kg/hr depending on the type of fodder material. Chaffed grass/straw mixed with leguminous material in the ratio of 1:1 is fed into the auger housing through the feeding hopper and is pressed and conveyed forward by the auger. Due to its screw type action, the fed material is pressed continuously against the pressure plate and finally comes out of the pressure plate in the form of briquettes.

Experiment No: 6
AIM: Familiarization with different solar energy gadgets.

Solar devices for renewable energy generation are available aplenty. But most of these are either chargers for mobiles and electronic devices or can be used when the battery is depleted.

Small solar energy chargers can be connected to different devices and also have built in battery for excess power storage. The ability to plug in directly into the main electricity makes the solar charger a favorable product. These devices charge at a much faster rate but most of the time their usefulness is limited to daytime hours. Solar energy battery packs focus on storing energy than charging the connected device directly.

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- Solar powered air conditioners should cool one's home inside while the sun is scorching outside.
- A portable solar water heater is designed to make available cheap and easy hot water. There is no need for any indoor plumbing or electricity here.

Some of the solar powered gadgets include:

1. Suaoki Solar Lantern

If your dream summer day includes a long hike followed by a night camping under the stars, the Suaoki Solar Lantern is your perfect companion. This water bottle doubles as a solar-powered lamp that will last for three to four hours. The solar lantern is collapsible and weighs only seven ounces — ideal for festivals like Austin City Limits where you need to stay hydrated in the day and locate your tent at night.

2. Skylock Solar-Powered Bike Lock

Riding a bike is a healthy and environmentally conscious transportation option, and the Skylock Solar-Powered Bike Lock takes things to the next level. This smart bike lock can connect to your smartphone for keyless entry, theft detection, crash alerts, and more. Don't worry if you live in an area without much sun — 12 hours of sunlight will fuel the Skylock for six months.

3. Innoo Tech Solar String Lights

Warm summer nights are best when they're enjoyed outside and in the company of friends. Save money and resources by hanging Innoo Tech Solar String Lights on your porch, deck, or patio to create the perfect atmosphere for good conversation and happy memories. These string lights last six to eight hours when fully charged, and can be set to turn on automatically when it becomes dark outside.

4. Solar Mosquito Repellant Light

Mosquito bites are a common plight in the summer months. Keep mosquitos at bay with the Solar Mosquito Repellant Light that deters mosquitos within 15 feet with no effects on humans. Weather resistant and portable enough to take to the beach or on picnics, its soft warm glow creates ambiance and a mosquito-free zone wherever it goes. Pair this with your other solar-powered camping gadgets for a solar powered camping trip.

5. Eton Rukus Bluetooth Solar-Powered Speaker

Enjoy your time on the beach even more this summer by playing music on your Eton Rukus Portable Bluetooth Solar-Powered Speaker — simply connect it with your smartphone, tablet, or computer. This wireless speaker system offers both AC and solar power, as well as a USB port for mobile charging. Its highly efficient monocrystal solar panel completely charges the internal

battery in under six hours, giving you over eight hours of music. Bring it to outdoor gatherings and pool parties, or relax in your own backyard.

6. WakaWaka Power + Solar Charger and Light

Most smartphones run out of battery before the day is over, and when you're on a hike without access to power outlets, you're left with a dead phone. The WakaWaka Power + Solar Charger and Light ensures you'll always be able to communicate with your friends and family and take pictures of the fun you're having on your summer adventures. This solar-powered device can fully recharge your smartphone battery in around two hours, while also providing up to 150 hours of light. If that isn't enough, when you buy a WakaWaka you also give a solar light to a family in need.

7. OWI 14-in-1 Solar Robot

When you're a parent, summer can sometimes feel like an ongoing attempt to keep kids entertained all day long. The OWI 14-in-1 Solar Robot is a solution to that problem. It transforms into 14 different shapes — including a dog, crab, car, and boat. Teach children how solar power can drive a small motor and keep them amused for hours. You might even find yourself joining in on playtime!

8. BirkSun Boost Classic

The BirkSun Boost Classic is a stylish and modern solar-powered backpack that will hold all of your festival essentials and ensure your electronic devices never run out of power. Its 3-watt solar panel is waterproof and has a USB port built in. It takes just five hours of sunlight to completely charge your smartphone, and the backpack's 15-inch laptop sleeve is fleece-lined for your computer's safety.

9. Solar Powered Entertainment Lounger

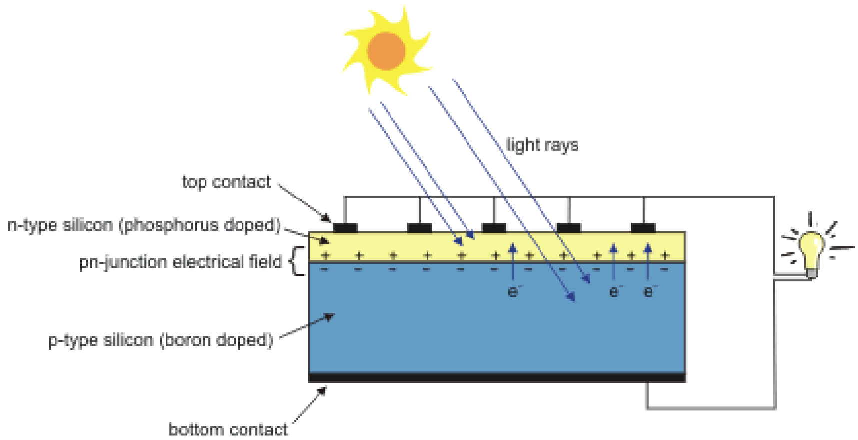
This Solar Powered Entertainment Lounger is the ultimate in sustainable poolside luxury. With it, you can charge your phone, adjust your lounging position, and play music or audiobooks through its built-in Bose speakers. You can also cool off with adjustable armrest misters and easily move with the sun thanks to its rear wheels. Just four hours of sun will charge the lounger's 10-watt solar panels to maximum capacity.

Experiment No: 7
AIM: To study solar photovoltaic system: solar light

How do PV panels or PV cells work?

When light hits a surface, it may be reflected, transmitted, or absorbed. Absorption of light is simply the conversion of the energy contained in the incident **photon** to some other form of energy. Typically, this energy is in the form of heat; however, some absorbing materials such as **photovoltaic (PV)** cells convert the incident photons into electrical energy (Messenger and Ventre 2004). A PV panel has one or more PV modules, which consist of connected PV cells. Figure 7.1 shows the schematic structure and operation of a PV cell.

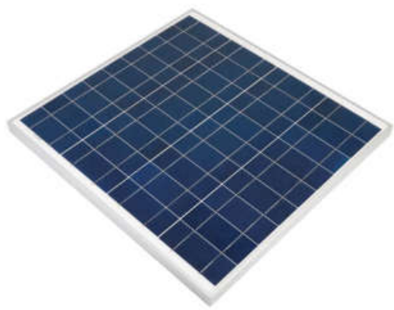
Figure 7.1 PV cell structure and operation schematic

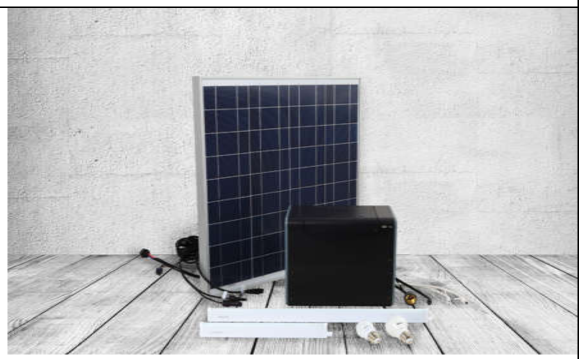


Typically, a silicon PV cell contains two layers. The top layer consists of a thin sheet of phosphorus-doped (negatively charged or n-type) silicon. Underneath this sheet is a thicker layer of boron-doped (positively charged or p-type) silicon. A unique characteristic of these two layers is that a positive-negative **(pn) junction** is created when these two materials are in contact. A pn junction is actually an electric field that is capable of creating an electrical potential when sunlight shines on the PV cell. When sunlight hits the PV cell, some of the electrons in the p-type silicon layer will be stimulated to move across the pn junction to the n-type silicon layer, causing the p-type layer to have a higher voltage potential than the n-type layer. This creates an electric current flow when the PV cell is connected to a load. The voltage potential created by a typical silicon PV cell is about 0.5 to 0.6 volts dc under open-circuit, no-load conditions. The power of a PV cell depends on the intensity of the solar radiation, the surface area of the PV cell, and its overall efficiency (FSEC 2005).

The efficiency of each individual PV cell directly determines the efficiency of the PV panel. PV cells can be categorized into different types according to their component materials and structural features. Efficiency of commercially available PV panels is typically 7-17% (Green et al. 2005).

Components of a Solar lighting System

Charge Controllers Solar Off-grid Control Unit(OCU) Charge Controller with Maximum Power Point Tracking is an advanced battery charger for off-grid photovoltaic lighting system. The controller features a leading and smart tracking algorithm that maximizes the energy harvest from the PV and provides load control to prevent over discharge of the battery.	
Batteries Valve Regulated Lead Acid(VRLA)Battery integrates Gel electrolyte technology with long service life, high performance in deep discharging; it can be used in wide range of ambient temperature and keep good performance of constant power input. Some of battery subsystem uses lead crystal(Gel) battery, which poses long cycle life time and delivers high efficiency with depth of discharge in long term run. The battery could be buried in-ground, which is accommodated in IP68(1.3m deep underwater, 3 months)box, and also could be placed in on-pole metal box in term of mounting type. On-pole battery subsystem comes with charge controller as well.	
Photovoltaic Panels PV Panel sub-system include panel and connectors; Solar Panel utilizes poly-crystalline and mono-crystalline silicon solar cells that combines high Wp (Watts Peak) output, affordability and efficiency. Some of the solar powered LED lighting system integrates highly efficient(up to 16%) and stable poly-crystalline silicon panel that generates positive power tolerance resulting in highly efficient system performance. Panels ranging from 35Wp to 295Wp are available in market and all panels are dedicated optimized with robust connectors to be working in outdoor tough conditions.	

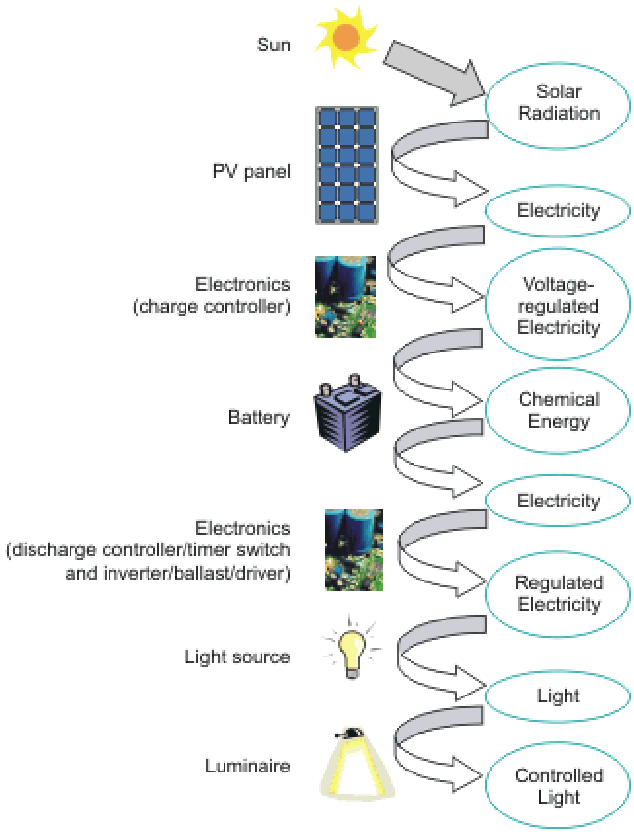
Controls Centralized Solar System offers long consistent power supply based on high quality Li-Fe battery, battery management system, MPPT photovoltaic charger, which brings long lifetime and low maintenance. On top of that, the bidirectional inverter can provide high quality power for the loads, to ensure loads work on continuous quality power supply. An integrated ultra-fast AC transfer switches ensure sensitive back-up loads working normally without outage occurs.	
Solar Indoor Products Solar Indoor Lighting system with innovative design really brings most light to your living, which enables your visionary indoor activities come true in evening, LED E27 lamps and LED battens are available in some of the system, giving you more sufficient light during evening in comfort and simplicity. In some cases, It is also able to power radio/TV via adaptor, standard USB ports are embedded to power USB-based device, like mobile phone and LED torch. High quality panel and battery(Gel or Lithium-ion battery).	
Accessories PV cable sub-system is for connecting PV panel and Charge Controller, Plug and Play connector ensures the easy wiring, IP67 protection. Generally all solar cable subsystem are available with connectors of plug-and play as well as fool-proof, which ensures the easy installation and reliability. Cable subsystem includes PV cable, luminaire extension cable, and battery cable	

How do PV lighting systems work?

In a **photovoltaic (PV)** lighting system, solar radiation replaces the burning of fossil fuels such as coal or natural gas or the harnessing of water power to generate the electricity necessary to power the lighting. A PV lighting system consists of a PV panel, battery, electronic circuits, light source (**lamp**), and **luminaire** (optics). Figure 7.2 illustrates the components in a typical PV lighting system.

PV panels transform solar energy into electrical energy. A PV panel is made up of many PV cells, which are created by semiconductor positive-negative **(pn) junctions** (see "How do PV panels or PV cells work?").

Figure 7.2 PV lighting system components and energy flow diagram



The electrical energy created by the PV cells can energize light sources (lamps) directly or be stored in a battery for later use. The dc current generated by the PV cell or the battery can be regulated and stabilized using an electronic circuit to energize dc light sources like incandescent, **light-emitting diodes (LED)**, or **fluorescent lamps** operated on dc **ballasts**; or they can be converted into 120 volts, 60 hertz ac to energize ac light sources such as fluorescent lamps operated on ac ballasts. Ac ballasts are more commonly available.

Electronic components, including charge controllers, timer switches, and ballasts for fluorescent lighting (or **drivers** for LEDs or **inverters** for ac lamps) provide regulation and control to the electric energy. The light source provides the light, and the luminaire that houses these components provides protection for the elements and optics to direct the light.

The light output of a PV lighting system depends on the amount of solar energy received and the efficiency or **efficacy** of its components, including the PV panel, battery, electronics, light source, and luminaire.

What information is needed to specify a PV lighting system?

In many ways, specifying a **photovoltaic (PV)**-powered lighting system is similar to specifying a **grid**-powered lighting system. However, expectations and design parameters must be altered if PV systems are to provide illumination effectively and economically. Additional information is also necessary to ensure that the PV system will supply the power needed to meet the requirements of a particular lighting **application** reliably. Some of the necessary information is provided in manufacturers' literature. The remainder can usually be obtained from a manufacturer's representative or distributor.

Determining application lighting requirements

The first step in specifying a PV lighting system is to determine if a PV system can realistically and economically meet the lighting needs of the application. In order to make this determination it is important to determine the application's lighting requirements. If the application requires relatively high nighttime light levels (greater than 1 **lux** on the ground) that is distributed uniformly over a large area for a long period of time (e.g., throughout the entire night), and is located in an area where the electric power grid is readily and easily accessible, a PV lighting system will most likely not be able to meet the lighting requirements reliably and cost effectively. An example of this type of application might be a parking lot or roadway that is located in an urban area and is used throughout the night.

A PV lighting system will most likely be able to meet the needs of a lighting application if one or more of the following points apply:

- Lower light levels, no more than 0.5 lux (5 moonlights), are considered appropriate for the application.
- The lighting system needs to operate for only a few hours (no more than eight) per night.
- Lighting needs to be provided only in limited areas of a site (e.g., to outline a path or pedestrian walkway).
- Small-scale **luminaires** are desirable for the application.
- The site is located in an area of the country where solar **irradiance** is plentiful throughout the year, or the site is only used when the solar irradiance is plentiful (i.e., summer).
- The electric power grid is not readily accessible and/or it would be costly to bring power to the site.
- The luminaires can be located in an area that will have non-shaded access to the sun for a majority of daylight hours and in which dirt is not likely to accumulate quickly on the PV panels.
- Financial subsidies are available through an electric utility, state energy office, or other entity, which would offset a significant portion of the capital costs for the PV lighting system.

If several of these points apply to the site under consideration, a lighting specifier may want to determine if a PV lighting system can meet the needs of the particular application cost effectively.

Selecting appropriate PV lighting equipment

When selecting lighting equipment for a particular application, it is important to understand the light output and distribution requirements of each luminaire. Once these requirements have been determined, a lighting specifier can select PV lighting equipment that will meet these specifications. Usually PV lighting equipment is purchased as a system that has already been assembled by a manufacturer, which contains the PV panel, batteries, electronics, luminaire, and other necessary components. In this case, a lighting specifier may want to check that the system will meet the lighting requirements of the application under consideration. The following information will be helpful.

Systems capacity

The information listed in the process below is needed in order to determine the system capacity or size requirements of a PV lighting system. The various system components (i.e., **lamps**, PV panels, electrical components) will degrade over time; therefore, a lighting specifier may need to over-design a PV lighting system (design it to exceed the minimum requirements of an installation) to ensure that it will continue to operate reliably over a long period of time.

Before determining energy requirements, first determine appropriate light levels for the application under consideration. For example, a high activity area may require a 10-lux system. A rural pathway, on the other hand, may need only a system with 0.5 lux illumination.

Step 1 - Determine energy requirements of the lighting system

The proper sizing of a PV lighting system depends on the watt-hours needed to operate the system each night. This is a function of the optical efficiency of the luminaire and the total number of lamp **lumens (lm)** needed, which will in turn determine the number of watts needed to provide those lumens. Once the total wattage of the lighting system (lamp and ballast or driver) is determined, this must be multiplied by the number of hours the system will operate each night. Therefore, the following information is needed:

- Luminaire efficiency
- Total number of lumens the lamp must produce (over time)
- Total wattage of the lighting system (lamp plus **ballast** or **driver**)
- Number of hours the lighting system will operate each night

Step 2 - Determine efficiency of system electronics

To ensure that the PV panels and batteries can provide the required energy for the lighting system, it is necessary to account for any losses that will occur in the system's electronics, such as charge controllers or dc-ac **inverters**. The efficiency of system electronics is usually given as a percentage. This will allow estimating how much of the battery's capacity will actually be available to power the lighting system. Therefore, it is necessary to know the efficiency of all system electronic components throughout their useful life.

Step 3 - Determine required battery storage capacity

Batteries are typically specified by the number of ampere- (amp) hours they are able to provide. To determine the number of amp-hours needed to provide the number of watt-hours required by the lighting system, it is necessary to know the voltage of the system. To convert watt-hours to amp-hours, divide the watt-hours by the voltage of the system. This will provide a rough estimation of the battery storage capacity needed for a particular system. It is also important to know how much of a battery's capacity is actually available for use. This is sometimes listed in manufacturer's literature as the battery's "usable amp-hours." Many batteries should only discharge 30% of their total storage capacity before being recharged. To check if the battery provided by the manufacturer is sized appropriately to meet the needs of a particular application or to specify battery capacity, the following information is needed:

- System voltage
- Usable amp-hours capacity of the battery (over time)
- Number of cycles for different discharge percentages

Step 4 - Determine the size of the solar panel needed

A crucial step in specifying a PV lighting system is to determine the size of the solar panel that will be needed to power the system reliably. This will vary based upon the area of the country in which the application is located (see "How does solar radiation vary by location?") and whether the design is for "worst case" or average solar radiation availability. Information avsailable on solar radiation charts typically specifies the number of kilowatt hours (kWhs) that can be produced per day in a particular location by a solar panel of one square meter. To determine if the solar panel you are considering is large enough to provide the energy required by a particular system, the following information is needed:

- The location of the lighting application
- The conversion efficiency of the solar panel being considered (over time)

Experiment No: 8
AIM: To study solar photovoltaic system: solar fencing

Components of solar power fencing system
Solar panel: Solar panel acts simply as a battery charger. It converts the sunlight directly in to DC current. A panel of 12 V/35 W capacity was used to change the 12 V/100 AH (Figure 8.1). The size of the solar panel depends upon the energizer size, power setting, geographical locations, level of usage, full year, and summer or spring autumn.

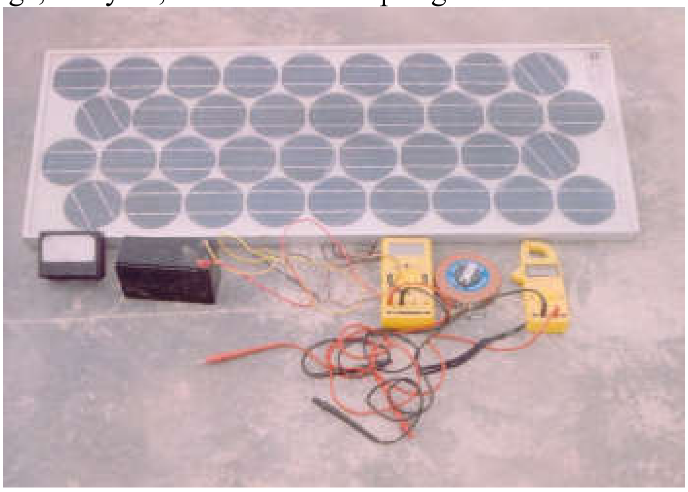


Figure 8.1 Solar photovoltaic panel, thermometer, solarimeter, digital voltmeter, digital ammeter

Battery: Battery acts as energy storage device (12 V/100AH). It stores the electricity generated by the solar panel, which allows the energizer to operate at night or during cloudy day. While selecting battery points should be considered, 1) It must be sufficient capacity to reliably power the energizer during winter and cloudy day, 2) designed for regular charge and discharge cycles without permanent damage by deep cycle, marine and leisure batteries.

Energizing device: It is the heart of solar power fencing system. It referred as unit controller, charger of fencer (Figure 8.2). It produces a short, high voltage pulse at a regular rate of one pulse per second. Each pulse was provided for 0.0003 second pulses are spaced about one second apart. Selection of the energizing device based upon type of animal, length of multi-wire fence, vegetation load on fence line, number of standards, and type of power source.

Figure 8.2 Energizing device (right side in box) and solar panel

Earthing system: The earthing system must be well adjusted in order to complete the pulse circuit and give an effective shock to animals. The earth (ground) system of the energizing device is similar to the radio antenna or aerial as shown in Figure 8.3. As a large radio requires a large antenna to effectively collect sound waves and high powered energizer requires large earth (ground) system to collect the large number of electrons from the soil earth (ground) system must be perfect of that the pulse can complete its circuit and give an effective shock to animal.

Figure 8.3 Earthing system

Fence system: The fence system consist of following components
Fence wire: It is used to apply the pulsating power through it. It is smooth one and made up of galvanized iron (G. I.) metal. A 2.5 mm (12.5 gauge) high tensile (H.T.) wire is recommended for electric fence systems because of its advantages .There are total eight wires, in present

system. The upper (top) one is live and lower one is earth wire. The live and earth wires are alternately placed.

Main post: It is a large diameter (Approximately 3-4 cm) and height 2.6 m galvanized iron pipe. After every 150 m distance it give great support to fence wire. The total numbers of main post in present systems are 24. It supports the 8 fence wires which run horizontally. It is also called corner or strainer post. The grouting is done at 60 to 75 cm depth with the help of cement concrete.

Supporting post: It is galvanized iron pipe having diameter 1 to 2 cm, used to support the main post from both sides.

T-post: The T-post is galvanized iron (G.I.) post of T cross section. It is used in between the two main posts to support or to mount the fence wire on it. It has height 2.6 m including 60-75 cm grouting. The distance between main post and T-post is six meter and the spacing between two T-post is also six meter.

Lightning diverter (lightning strikes) and choke kit: Lightning strikes can damage energizers. The damage can be minimized by disconnecting the energizer from the fence line and unplugging it from the power supply during electrical storms. An IG684K lightning diverter kit is recommended to minimize energizer damage. Lightning always finds the easiest way to earth (Figure 8.4). Therefore earth (ground) system of the lightning diverters must better than the energizer earth (ground).

Figure 8.4: Lightning diverter

Super earth kit: It consists of earthing rods of stainless steel (122 cm length) along with the earthing material bag. There are seven earthing rods at central farm for two units. Super strain insulator: They are high insulators used to join the fence wire to the main post, while running along its lengths. The strain insulator is specially designed plastic insulator. Its main function is to avoid direct contact between live fence wire and main post. PP real insulators: It is

specially designed insulator, used to mount the fence wires (live and earth both) on the support post and T- post. Its main function is to avoid the direct electrical contact between the live fence wire and t-posts also between live fence wire and support post. Permanent wire tightener and chain wire strainer: Wires can be tensioned by using a chain wire strainer with a built-in tension indicator or by using a permanent wire tightener. Tension in all wires 90 kg (200lbs). This is adequate tension for 2.5 mm (12.5 gauge) high tensile wire. For wild animal control the tension should be increased to 180 kg (400lbs), especially at the bottom wires. On long strains, it is recommended to place IG 643 permanent wire tightener in the centre of the fence so that the wire pulls in from both sides.

Tension springs: It is used in fence line to release the tension on fence line and protect them the breaking down. When animals are forced through electric fences bush fire or by dogs, in such situation the springs gets released which releases load or pressure on fence line and thus avoid the breaking down of fence line.

Double insulted lead out cable: This is one of the insulated cable used to give connections from battery to energizer, energizer to fence live line, energizer to earthing system; where, there is a gateways and in such similar conditions. G627 double insulated lead-out cable should be used in building, under gateways and where soil could corrode exposed galvanized wire.

Joint clamps: It is specially designed iron clamps used join one fence wire to another fence wire. In this fencing system, it is used to join the four live wire and four-earth wire.

Gateway and gates: The position of gateways is on flat, firm areas, away from sleep banks where erosion occurs. There should not use electric gates to get power across gateways.

Cutout switches: It is used to help find faults by isolating sections of the fencing system. Use two screws to attach a cut out switch to the inside a post from loop in tails from second wire and fasten securely to base of cut out switch. Attach incoming power cable to top of cut out switch using IG627 lead out cable.

Electrified flood gates: In heavy rainfall areas when the water level rises, an electric fence that is partly or entirely submerged may lose most of its pulse energy. The flood gate and IG604 flood gate controller will overcome this problem.

Live light: It help us in a flash if our power fence in effectively operating condition. It is nothing but flashing light to alert you. It is mounted on pipe post at top. It is visible from approximately 1000m at night. At 3KV or above, it flashes every pulse; at 2-3KV it flashes every second pulse; at less than 2 KV it does not flash.

Fence voltage alarm: Alarm on earth output and fence voltage alert you if any animal control is at risk. When voltage in live fence wire drops 3.6 KV due to any unusual fault, the fence voltage alarm get ON and siren gives a high frequency sound which alert you.

Performance efficiency of solar panel

From the data recorded, Input, output array and conversion efficiency calculated with following formulae given below.

Array output (AO), Watts = Voltage(V)×Current(A)

II). Input to arrays (IA), Watt = $G(W / m^2) \times A(m^2)$

Where, G - Incident solar radiation (W/m^2)

A - Panel Area (m^2)

Conversion efficiency, % = AO Watts ×100/ AI Watts

Working of solar power fencing system

The energizer has to be set up with its earth (ground) terminal coupled to an adequate earthing (grounding) system. The terminal is coupled to the live insulated wires of the fence. A correctly installed energizer sends an electric current along an insulted steel wire. As animal touches this live wire creates a path for the electric current through its body to the ground and back to the energizer via the earth (ground) system, thus complete the circuit. The greater the shock the animal receives more lasting the memory will be and more the fence will be avoided in the future. The shock felt is a combination of fence voltage and pulse time (energy). The higher the joule rating of the energizer the greater the shock and the greater the fence performance provided the installation is correct.

Evaluation of the solar power fencing system

The solar energy (light) is converted into D.C. electricity by using the solar panel, which is further stored in the rechargeable battery. This stored energy is then utilized for electrifying the fencing line at the night time and during cloudy weather. The voltage and current in fence line is measured by using the digital voltmeter and ammeter respectively. While measurement of voltage in fence wire with Digital Volt Meter (DVM) the one terminal or knob of DVM is connected to live wire and another terminal (earth terminal) is connected to earth fence wire or any post or touch to ground. The current in the fence line, it is always connected in series with fence live wire. It is observed that the voltage in fence line drops, when battery is not fully charged or discharge due to cloudy weather condition. The observations of fence voltage are recorded when battery is ¼ discharged, ½ discharged, ¾ discharged and fully discharged. The voltage in fence line also drops below 3.5 KV, when there is an unusual fault. After detection of fault by walking along fence wire line and inspecting fence line, it is removed by making power OFF in fence line with the help of cut-out switch. After removing the fault the fence voltage remains constant. The observations of fence voltage are recorded after every 500 m distance, with help of DVM (starting from energizer and ending to fence end).

Experiment No: 9
AIM: Study and working of solar photovoltaic pumping systems.

The solar water pumping system is a stand-alone system operating on power generated using solar PV (photovoltaic) system (Fig. 9.1). The power generated by solar cells is used for operating DC surface centrifugal mono-block pumpset for lifting water from bore / open well or water reservoir for minor irrigation and drinking water purpose. The system schematic is shown in the figure below. The system requires a shadow-free area for installation of the Solar Panel.

A Solar Photovoltaic (SPV) Water Pumping System consists of:

1. PV Array : Capacity in the range of 200 Wp to 10 KWp. These ranges of Solar Photovoltaic (SPV) Water Pumping Systems are basically for "Irrigation" applications. However, these may also be used for "Drinking Water Applications wherever such capacities are required". PV Array should be mounted on a suitable structure with a provision of tracking the sun.
2. Motor Pump Set (Surface or submersible) :
   - D.C. Motor Pump Set (with Brushes or Brush less D.C.)
     or
   - A.C. Induction Motor Pump Set with a suitable Inverter
3. Electronics :
   - Maximum Power Point Tracker (MPPT)
   - Inverter for A.C. Motors.
   - Electronic Protections.
4. Interconnect Cables and
5. On-Off switch.

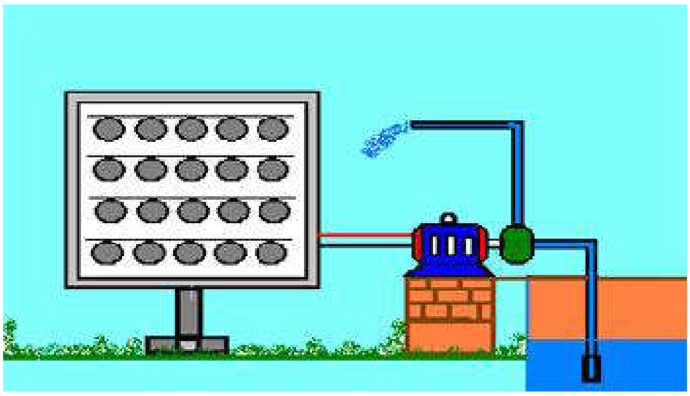


Fig.9.1 Schematic diagram of a solar water pumping system

Requirement of the Plant
The water requirement of plants varies with time and depends on the season and growth of plants. It is essential to irrigate optimally during the stage of flowering to fruit maturity. The type of soil and the climatic parameters are other factors that need to be considered. However, in the present study the peak water requirement of the plant is used to design the system and for that the following equation used.

$$W_r = \text{Crop Area}*PE*Pc*K_c*W_a/E_u$$

Where,
Wr = peak water requirement, (lit /day/plant)
Crop area= row to row spacing (m) × plant to plant spacing of the crop (m)
Pc = pan coefficient, approximately taken as 0.7 to 0.8
Kc = crop coefficient
PE = pan evaporation rate, (mm/day)
WA = wetted area, (%)
Eu = emission uniformity of drip system, (approx taken as 0.90)

Daily Insolation Levels
The power output from the PV array depends upon the insolation and availability of sun per day i.e. sunshine hours available on a particular location per day. The insolation varies from one location to another, month to month because of seasonal and climatic changes. If water requirement is in the same range of the whole year then solar design calculations is based on the month with the lowest insolation of the year. If water consumption varies round the year then the system design is based on the ratio of water required to the insolation available. The month in which this ratio is largest can determine the optimum PV array size in W/m^2
.

Orientation and Direction of the PV array
Orientation of the PV array is one of the most important aspects of the site assessment. The PV array is positioned in such a way that the sunlight is utilized to its maximum that is true south direction. The ideal orientation for panels is south as they will be exposed to the Sun for the maximum length of time during daylight hours, although other orientations still produce considerable amounts of power and attract significant tariff income. The local declination which depends on the location and changes with the times should, however, be taken into account.

Sizing and Selection of PV Module
The size of a PV array was calculated by using following equation
$E=\rho gHV/(3.6*10^6)$
Where,
E = hydraulic energy required (kWh/day)
ρ = density of water (1000 kg/m3)
g = gravitational acceleration (9.81 m/sec2)
H = total hydraulic head (m)
V = volume of water required (m3/day)
By putting above all values, equation reduces as shown below;
E=0.002725HV (kWh/day)

Experiment No: 10
AIM: To study and find the efficiency of solar cooker

Solar cooking utilizes (1) a sun-following broiler-type device with a metallized parabolic reflector and a grid in the focal area where cooking pots can be placed; (2) an oven-type cooker comprising an insulated box with glass covers over an open end which is pointed toward the sun. When reflecting wings are used to increase the solar input, temperatures as high as 400 ^{0}F (204 ^{0}C) are reached at midday. Large solar cookers for community cooking in third world country villages can be floated on water and thus easily adjusted to point at the sun. For cooking when the sun does not shine, oils or other fluids can be heated to a high temperature, 800^{0}F (around 425^{0}C), with a solar concentrator when the sun shines, and then stored. A range similar to an electric range but with the hot oil flowing through the coils, at adjustable rates, is then used to cook with solar energy 24 h/day.

Box type solar cooker
This type of solar cooker, commonly known as a hot box, consists of a well insulated box, the inside of which is painted dull black and is covered by one or more transparent covers. The purpose of these transparent covers is to trap heat inside the solar cooker. These covers allow the radiation from the sun to come inside but do not allow the heat from the hot black absorbing plate to come out of the box. Because of this the temperature of the blackened plate inside the box increases and can heat up the space inside to temperature up to 140 ◦C which is adequate for cooking. The box type solar cooker has reached the commercialization stage. The important parts of a simple box type solar cooker are:
(1) *Outer box*
The outer box of a solar cooker may be made of wood, iron sheet or fiber reinforced plastic with suitable dimensions.
(2) *Inner box*
The inner box can be made from galvanized iron or mild steel or aluminum sheet. All four sides and the bottom of the inner box which are exposed to the sun are coated with blackboard paint which absorbs solar radiation.
(3) *Thermal insulation*
The space between the outer box and the inner box is fitted with insulating material such as glass wool, thermocole, etc. This prevents heat losses from the cookers.
(4) *Double glazing*
Generally a double glass cover is provided for a solar cooker. These covers have length and breadth slightly greater than the inner box and can be fixed in a wooden frame maintaining a small spacing between the two glasses. This space contains air which acts as an insulator and prevents heat escaping from inside. The wooden frame is attached to the outer box by means of hinges. A rubber strip is affixed all around on the edges of this frame to prevent any heat leakage.
(5) Mirror
A mirror is used in a solar cooker to increase the radiation input on the absorbing surface. Sunlight incident on the mirror gets reflected from it and enters the box after passing through the glass covers. This radiation is in addition to the radiation entering the box directly and helps to quicken the cooking process by raising the inside temperature of the cooker. The use of a mirror can enhance the solar radiation input to the cooker by about 50 per cent.

(6) *Cooking containers*
The cooking containers are generally made of aluminum or stainless steel. The containers are painted dull black on the outer surface so that they also absorb radiation directly.

The schematic diagram of a box type solar cooker is shown in Fig. 10.1.

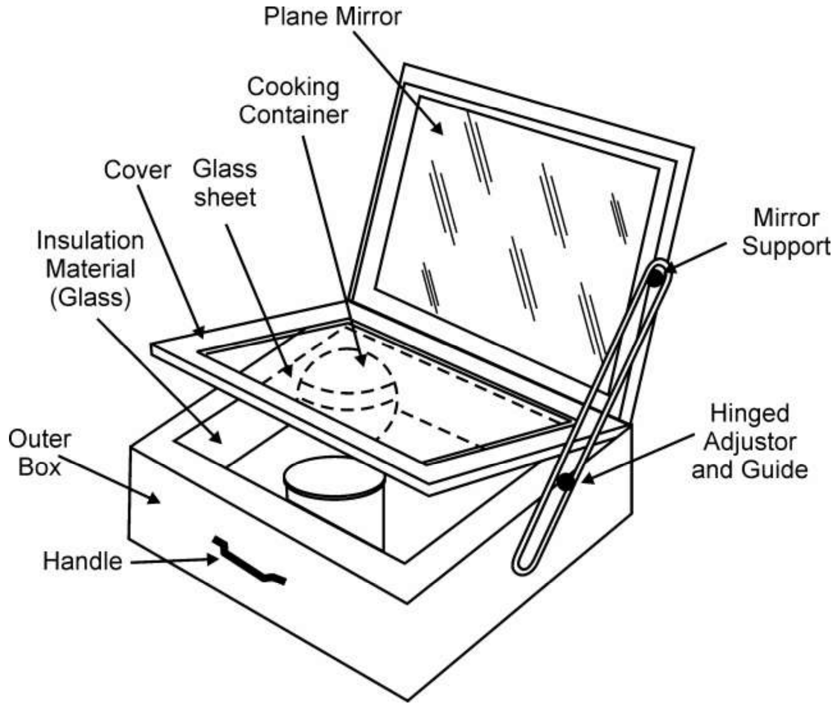


Fig. 10.1 Schematic view of box type solar cooker.

Advanced type solar cooker

It is a separate collector and cooking chamber type solar cooker where solar energy is collected at a separate place with the help of either a flat plate or focusing collector and then this stored heat is transferred to the cooking vessel placed either at a separate place. Further, here the cooking in some cases can either be done with stored heat or the solar heat is directly transferred to the cooking vessel in the kitchen.

Advantages of solar cooker

The solar cooker has a number of advantages over the traditional cooking devices. These are:
1. It preserves the nutrition value of the food (because the cooking is done at low temperature).
2. It does not require constant attention.
3. It saves time for the housewife.
4. It is pollution free.
5. It is safe and simple.
6. It saves money and fuel.
7. It helps in preserving our environment.
8. It keeps the food hot for a long time.

Calculations:

Energy efficiency
Based on the 1st Law of Thermodynamics:
Energy input = Enery output + Energy loss

Energy input to the solar cooker can be calculated as follows:

$$\mathbf{E_i = I_t \times A_{sc}}$$

Where:

E_i is the energy input in W
I_t is total solar energy incident upon plane of the solar air being heated in W/m^2
A_{sc} is the surface area of the solar cooker

Energy output from the Solar cooker can be found as below:

$$\mathbf{E_o = m_w c_{pw}(T_{wf} - T_{wi})/t}$$

Where:

E_o is the energy output in W
M_w is the mass of water in kg
C_{pw} is specific heat of water in J/kgK
A_{sc} is the surface area of the solar cooker
T_{wi} is the initial temperature of the water in K
T_{wf} is the final temperature of the water in K
t is the time in seconds

Energy efficiency of the solar cooker can be found as below:

$$\eta = \text{Energy output/ Energy input} = E_o/E_i$$
$$= m_w c_{pw}(T_{wf} - T_{wi})/[t \times I_t \times A_{sc}]$$

Experiment No: 11
AIM: To study and find the performance of solar dryers

One of the traditional uses of solar energy has been for drying of agricultural products. The drying process removes moisture and helps in preservation of the product. Traditionally drying is done on open ground. The disadvantages associated with the traditional system of drying are slow process, uncontrolled drying, quality deterioration, and losses due to birds, rodents and insects. Drying under solar cabinet or convective dryers can be done faster and in a controlled condition.

Cabinet dryer A cabinet type solar dryer is suitable for small scale use. The dryer consists of an enclosure with a transparent cover. The material to be dried is placed on the perforated trays. The solar radiation entering the enclosure is absorbed in the product itself and the surrounding internal surfaces of the enclosure (Fig. 11.1). As a result, moisture is removed from the product and the air inside is heated. Suitable openings at the bottom and top ensure a natural circulation. Temperature from **50-80ºC** is attained and drying time ranges from **2-4 days**. Products like dates, apricots, grapes, chillies, turmeric etc., can be dried in a cabinet dryer.

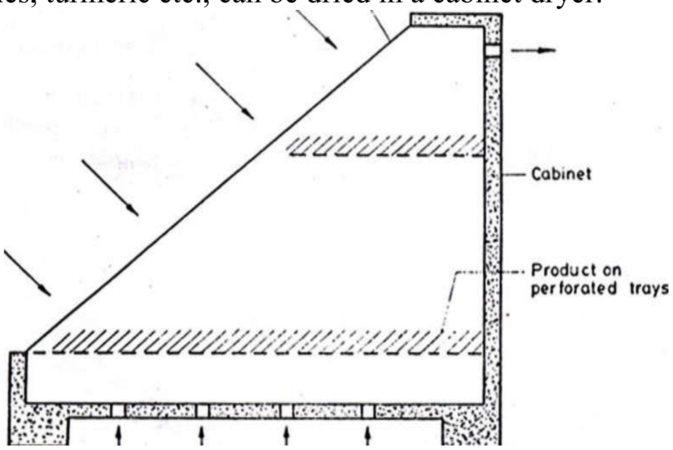


Fig. 11.1 Schematic diagram of cabinet dryer.

Convective dryer

For large scale drying, convective dryer is used. In this dryer, the solar radiation does not fall on the product to be dried. Air is heated separately in a solar air heater and then forced into the chamber in which the product to be dried is placed. A blower circulates the air from the heater to the grain hopper (Fig. 11.2). These dryers are suitable for food grains, tea, tobacco, spices etc. In India about 10,000m2 of collector area for drying various kinds of crops and food products and for drying timber has been installed in about 50 industries.

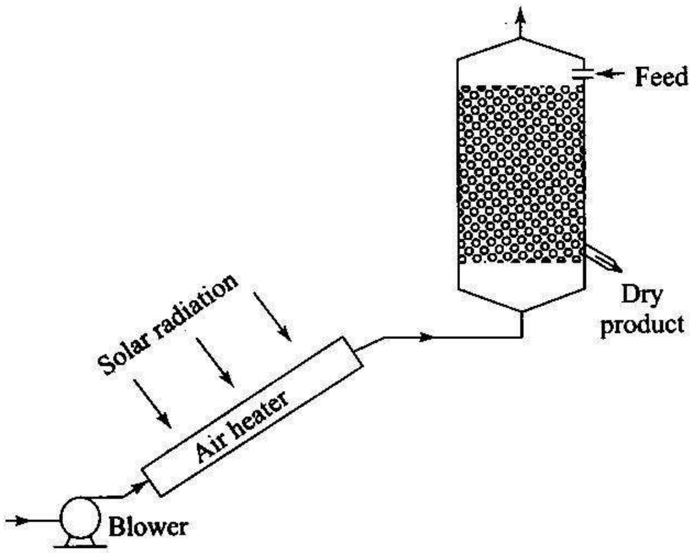


Fig.11.2 Schematic diagram of convective dryer

Solar driers can be constructed out of ordinary, locally available materials, making them well suited for domestic manufacture.

Most solar dryer designs fall into three main types: direct, indirect and mixed-mode. In a direct solar dryer, the product absorbs solar energy that enters through a transparent cover. Direct solar radiation dries the produce while the drying chamber protects the produce from environmental elements. Indirect dryers have a separate compartment called the collector, in which the air from the outside passes through and is heated before entering the drying chamber containing the produce. The hot air flow provides the necessary heat to help evaporate moisture from the produce as well as carry the evaporated moisture out of the dryer.

A mixed-mode dryer combines the features of the direct mode and indirect mode dryers. The produce is dried concurrently by both direct radiation and by natural convection from the collector heating the entering air. The mixed-mode dryer has been found to be the most effective in terms of the time it takes to dry the produce.

It is important for a solar dryer to be operational in partially cloudy, hazy and sunny environments. Increasing the collector area increases the area available for insolation and thus reduces the drying time. However, increased collector area subsequently leads to increased capital cost and more space required for a larger solar dryer. To solve this problem, reflective solar panels may be used to inexpensively increase the heat output of the collectors used for indirect dryers. They can focus additional radiation into the drying chamber and allow dryers to operate in low insolation environments.

Basic theory of operation

The main goal of solar drying is to remove moisture from the fruit or vegetable to a level that will prevent microbial growth (≤20% wet bulb in this study) while maintaining acceptable quality of the product. The drying rate also depends on the rate of mass transfer of moisture from

the interior of the produce to the surface of the produce. During drying, the produce structural changes cause a reduction in moisture transport inside the produce.

The mixed-mode dryers are composed of three main parts. The solar collector where the air is heated by the radiation emitted by the solar absorber, the drying chamber where the produce is exposed to the hot air from the collector and the direct radiation, and the outlet chimney which aides the exhaust ofmoist airwhile utilizing a buoyancy effect.

The latent heat of vaporization required to remove moisture from the produce is provided by the hot air flowing through the dryer and by the direct radiation striking the tomatoes in the drying chamber.

The air flow in the dryer is responsible for carrying away the evaporated moisture from the produce. The moisture leaving the produce is equal to the moisture entering the air stream by convection.

$$\rho_f \Delta M/\Delta t = -G\ \Delta H/\Delta x$$

where

ρf=density of the dry matter of the food (kg/m3),
M=moisture content (d.b.),
t=time (h),
G=air flux (kg/m^2hr),
H=humidity (kg/kg) and
x=depth of the bulk (m).

The air flow through the dryer is an important factor in the drying process and is responsible for moisture transport by enhancing convective transfer of water vapor from the tomato to the dry surrounding air. Humidity and temperature determine the dryness or drying power of the atmosphere. However, temperature and relative humidity by themselves can be poor predictors of dryer success. The vapor pressure deficit (VPD) is often a more important variable in modeling the drying process because it combines both relative humidity and temperature into a single number.

Vapor pressure deficit is the difference between the current amount of moisture in the air and the amount of moisture the air can hold when it is fully saturated. It quantifies how close the dryer air is to saturation. The VPD calculation is more appropriate to report over the relative humidity measurement because the VPD measurement includes the relative humidity measurement as well as the temperature measurement. This is important because the temperature has an effect on the moisture holding ability of the air, which approximately doubles with every 10 °C increase in temperature. The drying process within the constructed dryers is an extremely complex heat and mass transfer process that depends on insolation level, air temperature, air humidity and the air flow rate through the dryer. In addition, the specific drying properties of a product of interest affect the drying process as well.

Calculations:

The daily overall system drying efficiency, ηd, is a measure of the overall effectiveness of a drying system, including air heater and dryer chamber. It is the ratio of energy required to

evaporate the moisture from the product to the energy supplied to the solar dryer; which takes into account the energy consumed by the blower for forced convection solar dryers.

$\eta_d = W_v L/(IAt+Q_b)$

where
L is the latent heat of vaporization,
Wv [kg] the mass of water content removal,
A – the area of dryer,
I – the solar radiation,
t – the interval of time between two measurements, and
*Q*b – the blower energy delivered to the solar dryer in time, *t* [kJ].

Experiment No: 12
AIM: To study solar distillation and solar pond.

Solar Distillation
The supply of potable water is a major problem in underdeveloped as well as some developing countries due to pollution developed in underground water due to various human activities. It has caused a scarcity of fresh water in many towns and villages near lakes and rivers. Along with food and air, good quality water is a basic necessity for man. Man has been dependent on rivers, lakes and underground water reservoirs for fresh water. Survey show that about 79 % of water available on the Earth is salty, only 1 % fresh. The remaining 20 % is brackish.

Distillation of brackish/saline water is a good method to obtain fresh water (potable water). However, the conventional distillation processes such as multieffect evaporation, multistage fresh evaporation, thin-film distillation, reverse osmosis and electrodialysis are energy intensive techniques. Therefore, solar distillation is an attractive alternative due to its simple technology and nonrequirement of highly skilled labour for maintenance work and low energy consumption. As such, it can be used at any place without much problem.

Covering swimming pools, ponds, or basins with airtight covers (glass or plastic) will condense the water vapors on the underside of the covers. The condensate produced by the solar energy can be collected in troughs as distilled water. Deep-basin stills have a water depth of several feet (between approximately 0.5 and 1.5 m) and require renewal only every few months. Shallow-basin stills have a water depth of about 0.5 to 2.0 in (approximately 1 to 5 cm) and have to be fed and flushed out frequently. The glass-covered roof-type solar still is in wide use in arid areas for the production of drinking water from salty or brackish sources. The sun's rays enter through the cover glasses, warm the water, and thus produce vapor which condenses on the inner surface of the cover. Daily yield ranges from 0.4 lb/ft^2 (2kg/m^2) of water surface in winter to 1.0 lb/ft^2 (5 kg/m^2) in summer.

Inflated plastic films have also been used to cover solar stills, but their greatest success has been achieved in controlled environment greenhouses where the vapor which transpires from plant leaves is condensed and reused at the plant roots. Stills made of inflatable plastic also are equipment in survival kits, on lifeboats, etc.

A single basin solar still (Fig. 12.1) is covered by sloped glass or plastic where the evaporated water is condensed and lead into a rainwater channel. The darker the color of the basin, the more sunlight is turned into heat.

The clean water output is higher in the evening due to greater temperature differences between warm water on the inside of the device and the outside ambient air.

A stationary installation should be made out a glass basin to ensure longevity, but plastic would be better for a portable solar still.

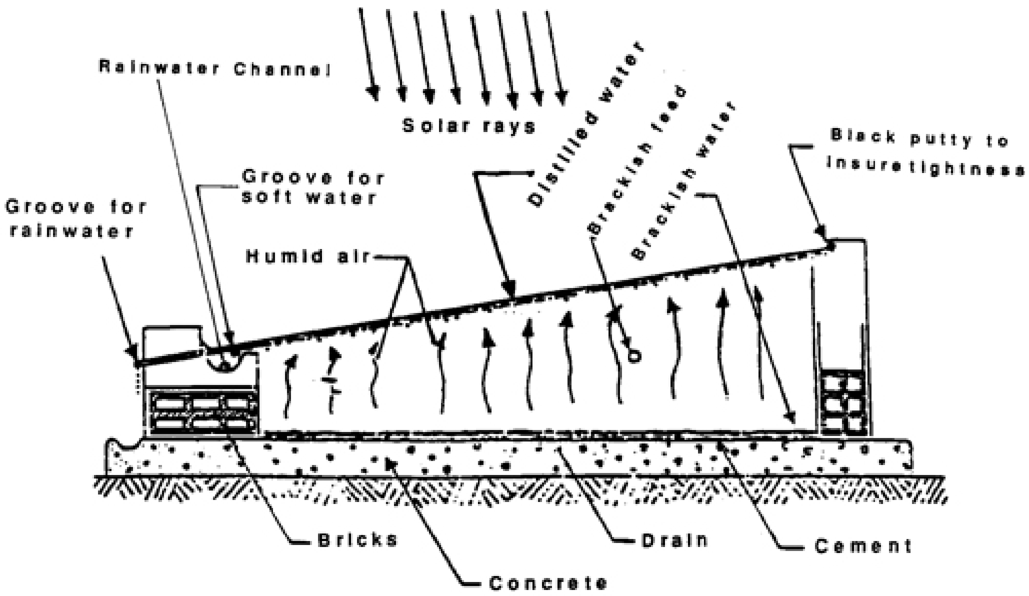


Figure 12.1 Single Basin Solar Still

Solar Ponds If water in ponds or reservoirs contains salts in solution, the warmer layers will have higher concentrations and, being heavier, will sink to the bottom. The hot water on the bottom is insulated against heat losses by the cooler layers above. Heat can be extracted from these ponds for power generation. Solar ponds are, effectively, large inexpensive solar collectors. Their heat can be used to power vapor engines and turbines; these, in turn, drive electric generators.
A solar pond is a large-area collector of solar energy resembling a pond that stores heat, which is then available to use for practical purposes. Researched designs include saltwater ponds, gel ponds, and others such as shallow ponds with covers, deep ponds with glass or plastic containment devices. Their common features are to store the energy in the incoming solar radiation in the heated depths of the pond, and to suppress the convection currents that would otherwise lead to heat loss to the surroundings.

The most common form of solar pond is a salt-water solar pond. Salt water ponds exist naturally in a variety of locations, the first ponds being discovered in Eastern Europe at the beginning of the 20th century at a natural salt lake in Transylvania. Most of the salt water ponds operated today, however, are artificial, simulating natural solar ponds but taking advantage of engineering technologies to advance their operation and application for practical purposes.

A solar pond has three zones. The top zone is the surface zone, or UCZ (Upper Convective Zone), which is at atmospheric temperature and has little salt content. The bottom zone is very hot, 70°– 85° C, and is very salty. It is this zone that collects and stores solar energy in the form of heat, and is, therefore, known as the storage zone or LCZ (Lower Convective Zone). Separating these two zones is the important gradient zone or NCZ (Non-Convective Zone). Here the salt content increases as depth increases, thereby creating a salinity or density gradient.

The key feature of a salt-water solar pond is that it has increasing amounts of salts dissolved in the water with depth (Figure 12.2). The salinity and hence density of each level of the pond thus increases with depth, so it is often called a 'salt stabilised' or 'salinity-gradient' solar ponds. Below this salinity-gradient zone there is a layer of nearsaturated salt solution, the 'storage zone', and above it there is a thin layer of fresh or low-salinity water, the surface zone. The storage zone is typically one or two metres thick, and the overall pond two or more metres deep.

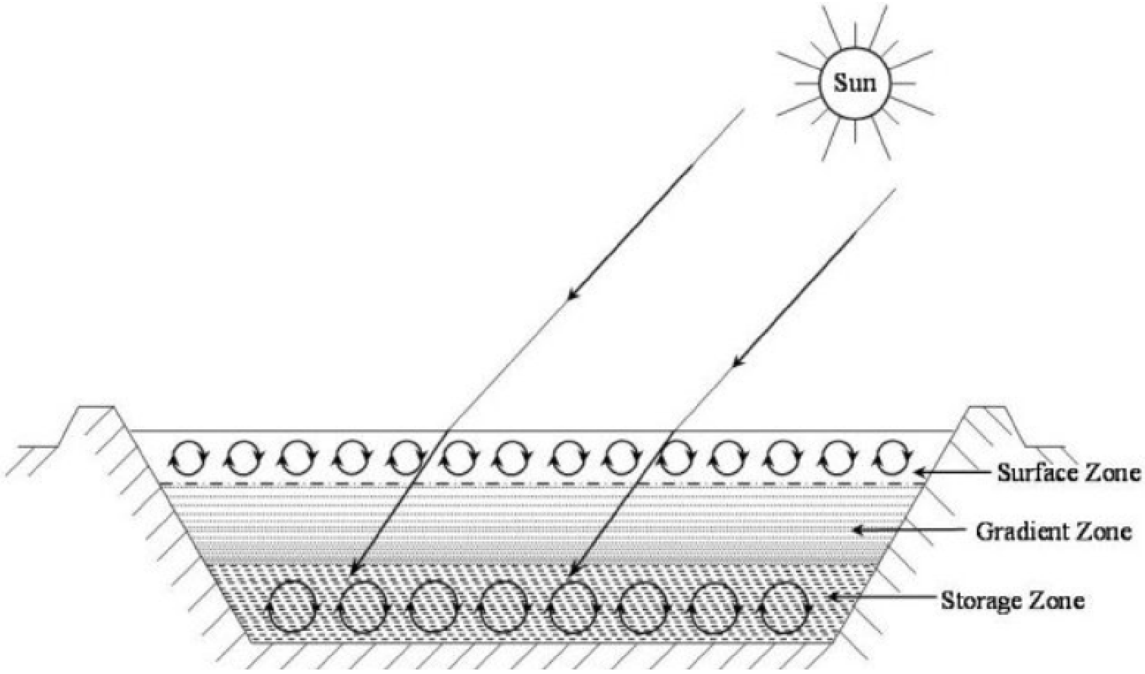


Figure 12.2 Schematic representation of a salinity-gradient solar pond

Much of the incoming solar radiation reaches the storage zone at the bottom of the pond where it heats up the concentrated salt solution there. Heat loss upwards in the pond from the storage zone is prevented since natural convection currents in the gradient zone are suppressed. This suppression and hence insulating effect occurs because of the density gradient present (Figure 12.3). As a particular layer of solution is heated from below its density is slightly reduced, but remains higher than that of the layer above. Hence there can be no movement upwards by the 'buoyancy' effect that drives natural convection in a normal body of water without such a density gradient.

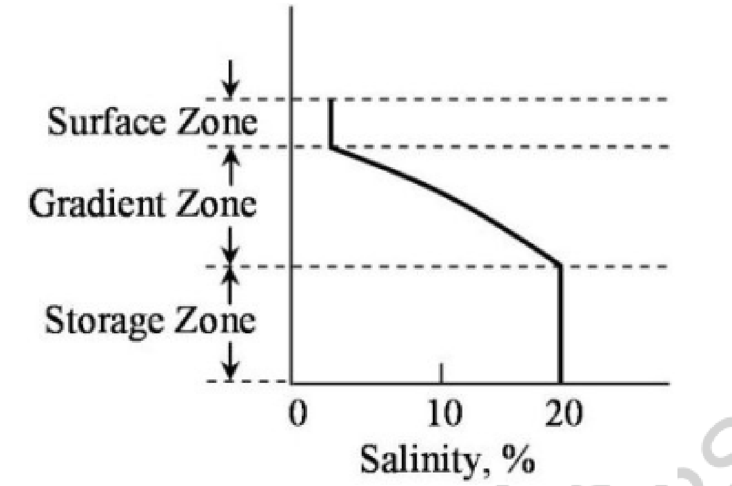


Figure 12.3 Salinity profile in a solar pond

The main process of heat loss from the storage zone has thus been halted, and while there are small heat losses by conduction through bottom and sides of the pond the storage zone heats up and retains this thermal energy until it is withdrawn for use. Temperatures above 80°C can be obtained in periods of high solar radiation, and elevated temperatures over ambient are maintained overnight and to some extent from summer to winter too (Figure 12.4)

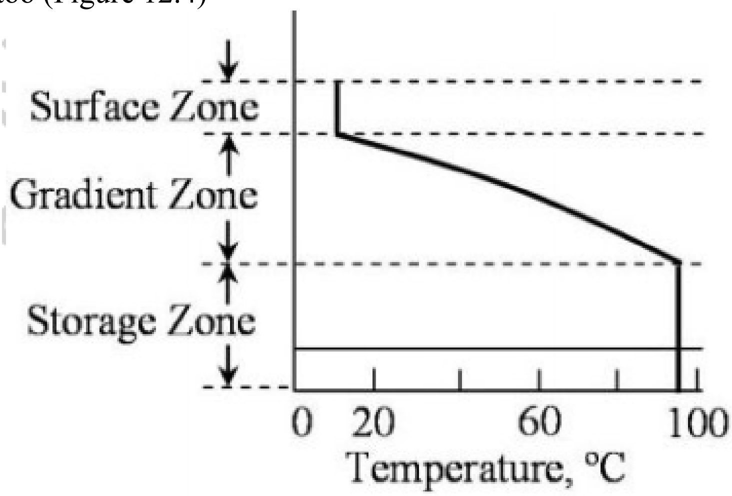


Figure 12.4 Temperature profile in a solar pond

Experiment No: 13
AIM: To study the production process of bio-fuels.

A **biofuel** is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter.

Biofuels can be derived directly from plants, or indirectly from agricultural, commercial, domestic, and/or industrial wastes.[1] Renewable biofuels generally involve contemporary carbon fixation, such as those that occur in plants or microalgae through the process of photosynthesis. Other renewable biofuels are made through the use or conversion of biomass (referring to recently living organisms, most often referring to plants or plant-derived materials). This biomass can be converted to convenient energy-containing substances in three different ways: thermal conversion, chemical conversion, and biochemical conversion. This biomass conversion can result in fuel in solid, liquid, or gas form. This new biomass can also be used directly for biofuels.

BIOFUEL TYPES AND PROCESS – *Bioethanol production*: conversion of starch or sugar-rich biomass (corn(maize), other cereals, sugar cane, etc.) into sugar, fermentation, and distillation. *Advanced process*: hydrolysis of ligno-cellulosic biomass, fermentation and distillation. *Biodiesel production*: extraction and esterification of vegetable oils, used cooking oils and animal fats using alcohols. *Advanced processes*: hydrogenation of oil and fat; gasification and catalytic conversion to liquid fuels (biomass to liquid, BTL). *Biomethane*: biogas from anaerobic digestors and landfills used as compressed gas in natural gas vehicles.

ENERGY INPUT AND EMISSIONS – Because of the variety of feedstocks and processes, figures vary widely and make it difficult to identify indicative values. *Sugar-cane ethanol*: fossil fuel input some 10%-12% of final energy and up to 90% CO_2 reduction compared with gasoline. *Corn ethanol*: high energy input and much smaller CO_2 reduction (15-25%). *Ligno-cellulosic ethanol*: total energy input may be higher than for corn ethanol, but most such energy could be provided from biomass itself, with CO_2 reduction up to 70% (100% with power co-generation). *Biodiesel*: about 30% energy input and up to 60% CO_2 reduction.

POTENTIAL – *Ethanol*: Low ethanol-gasoline blends (5%-10%, E5-E10) can fuel gasoline vehicles with little if any engine modification. New flexi-fuel vehicles run on up to 85% blends. *Ligno-cellulosic ethanol* (from all kinds of biomass) may greatly increase feedstock variety and quantity, but requires further R&D. Several pilot/demo plants in operation in 2006-2007. Potential market: 45 EJ by 2050. *Biodiesel*: Low biodiesel-diesel blends (B5-B10) can fuel diesel vehicles with no engine change; low sulphur and particulate emissions. Synthetic biodiesel (BTL) is fully compatible with diesel fuel and engines. Potential market: 20 EJ by 2050. Global biomass potential is some 100-200 EJ per year by 2050 (10%-20% of total energy supply).

BARRIERS – Competition with food and fibre production for use of arable land; cost; regional market

structure; biomass transport; lack of well managed agricultural practices in emerging economies; water and fertiliser use; conservation of bio-diversity; logistics and distribution networks.

PROCESS - „ **Bioethanol conventional production –** Bioethanol is the most common biofuel, accounting for more than 90% of total biofuel usage. Conventional production is a well known process based on enzymatic conversion of starchy biomass into sugars, and/or fermentation of 6-carbon sugars with final distillation of ethanol to fuel grade. Ethanol can be produced from many feedstocks, including cereal crops, corn (maize), sugar cane, sugar beets, potatoes, sorghum, cassava. Coproducts (e.g animal feed) help reduce production cost. If sugar cane is used, conversion into sugar is easier. Crushed stalk (bagasse) can be used to provide heat and power for the process and for other energy applications. The world's largest producers of bio-ethanol are Brazil (sugar-cane ethanol) and the United States (corn ethanol). Ethanol is used in low 5%-10% blends with gasoline (E5, E10) but also as E-85 in flex-fuel vehicles. In Brazil, gasoline must contain a minimum of 22% bioethanol. „

Bioethanol advanced production - While conventional processes use only the sugar and starch biomass components, R&D focuses on advanced processes that utilise the all available ligno-cellulosic materials. These processes hold the potential to increase variety and quantity of suitable feedstock including cellulosic wastes, maize stover, cereal straw, food processing wastes, as well as dedicated fast-growing plants such as poplar trees and switch-grass. Cellulosic feedstock could be grown on non arable land or be produced from integrated crops, which could considerably increase land availability.

Ethanol production from ligno-cellulosic feedstock includes biomass pre-treatment to release cellulose and hemicellulose, hydrolysis to release fermentable 5- and 6-carbon sugars, sugar fermentation, separation of solid residues and non-hydrolysed cellulose, and distillation to fuel grade.. To provide better conversion, new chemical and enzymatic processes (pre-treatment, hydrolysis, fermentation) are being examined. Solid residues and coproducts from the process such as lignin and other components, particularly from forest materials, may inhibit hydrolysis. They can be extracted and used as a fuel in the production process, thus reducing cost and emissions.

Biodiesel production – Biodiesel production is based on trans-esterification of vegetable oils and fats through the addition of methanol (or other alcohols) and a catalyst, giving glycerol as a co-product. Feedstock includes rapeseeds, sunflower seeds, soy seeds and palm oil seeds from which the oil is extracted chemically or mechanically. **Advanced processes** include the replacement of methanol of fossil origin, by bioethanol to produce fatty acid ethyl ester instead of fatty acid methyl ether (the latter being the traditional biodiesel). In order to expand the relatively small resource base of biodiesel, new processes have been developed to use recycled cooking oils and animal fats though these are limited in volume. **Hydrogenation of oils and fats** is a new process that is entering the market. It can produce a biodiesel that can be blended with fossil diesel up to 50% without any engine modifications. **Synthetic biofuel production** via biomass gasification and catalytic conversion to liquid using Fischer-Tropsch process (biomass conversion to liquids BTL) offers a variety of potential biofuel production processes that may be suited to current and future engine technologies. The largest biodiesel producer is Germany, which accounts for 50% of global production. Biodiesel is currently most often used in 5%-20%

blends (B5, B20) with conventional diesel, or even in pure B100 form. Stages of biodiesel production, algae processing and ethanol production from cellulose is shown in Fig. 13.1, 13.2 and Fig. 13.3 respectively.

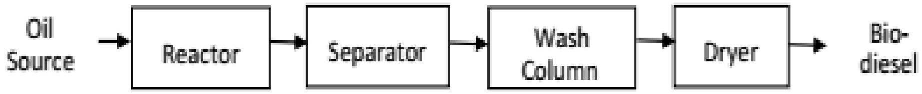


Figure 13.1: Stages of biodiesel production

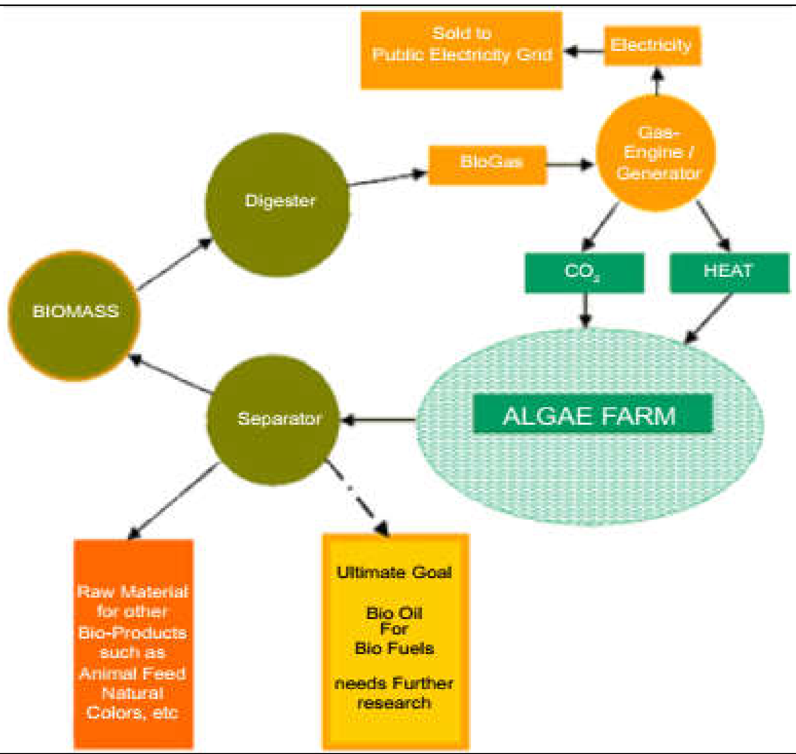


Figure 13.2: Algae processing

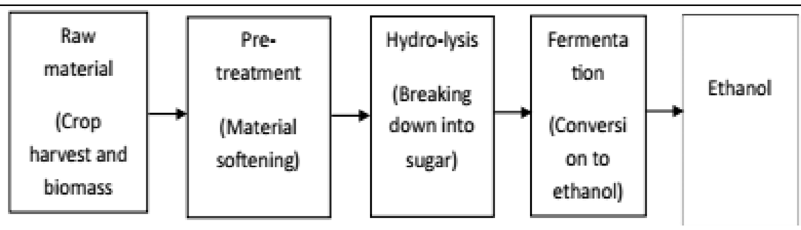


Figure `13.3. Production of ethanol from cellulose.

ENERGY INPUT AND EMISSIONS – Fossil energy inputs and emissions levels from biofuel production are sensitive to process and feedstock, to energy embedded in fertilizers, and to local conditions.

Production of ethanol from sugar cane (Brazil) is energy-efficient since the crop produces high yields per hectare and the sugar is relatively easy to extract. If bagasse is used to provide the heat and power for the process, and ethanol and biodiesel are used for crop production and transport, the fossil energy input needed for each ethanol energy unit can be very low compared with 60%-80% for ethanol from grains. As a consequence, ethanol well-towheels CO_2 emissions can be as low as 0.2-0.3 kgCO_2/litre ethanol compared with 2.8 kg CO_2/litre for conventional gasoline (90% reduction). Ethanol from sugar beet requires more energy input and provides 50%- 60% emission reduction compared with gasoline.

Ethanol production from cereals and corn (maize) can be even more energy-intensive and debate exists on the net energy gain. Estimates, which are very sensitive to the process used, suggest that ethanol from maize may displace petroleum use by up to 95%, but total fossil energy input currently amounts to some 60%-80% of the energy contained in the final fuel (20% diesel fuel, the rest being coal and natural gas) and hence the CO_2 emissions reduction may be as low as 15%-25% vs. gasoline. „

Ethanol from ligno-cellulosic feedstock – At present, the total energy input needed for the production process may be even higher as compared to bioethanol from corn, but in some cases most of such energy can be provided by the biomass feedstock itself. Net CO_2 emissions reduction from ligno-cellulosic ethanol can therefore be close to 70% vs. gasoline, and could approach 100% if electricity co-generation displaced gas or coal-fired electricity. Current R&D aims to exploit the large potential from improving efficiency in enzymatic hydrolysis. „ Energy input and overall emissions for **biodiesel** production also depend on feedstock and process. Typical values are fossil fuel inputs of 30% and CO_2 emission reductions of 40%-60% vs. diesel. Using recycled oils and animal fats reduces the CO_2 emissions.

Production technique of biofuel and oil yield potential of different crops is shown in tabular form below in Table 13.1 and 13.2 respectively.

Table 13.1: Production technique of biofuel

Raw material	Technique	Product	Product type
Vegetable oil and animal fat	Hydrotreatment	Biodiesel	Hydro-treated biodiesel
Algae	Fermentation, extraction and Esterifcation	Biodiesel etc.	Algal biodiesel
Lignocellulosic material	Advanced hydrolysis & fermentation	Biomass-to-liquids (BTL): Fischer-Tropsch (FT) diesel synthetic (bio) diesel	Synthetic biodiesel
Lignocellulosic material	Advance hydrolysis and fermentation	Cellulosic bioethanol	Bioethanol

Table 13.2: Oil yield potential of different crops.

Sl. No.	Crop type	Oil yield potential (‘000 l/ha)	Sl. No.	Crop type	Oil yield potential (‘000 l/ha)
1	Microalgae	47.5-142.5	5	Rapeseed	1.2
2	Oil Palm	6.0	6	Sunflower	1.0
3	Jatropha	2.0	7	Soybean	0.5
4	Canola	1.25	8	Corn	0.2